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NOVEL FIBRE METAL LAMINATES WITH HIGH IMPACT STRENGTH AND INTERNAL ENERGY DISSIPATION

This invention relates to improvements of mechanical properties of composite materials (Fibre Metal Laminates), particularly their impact properties.

In comparison with traditional structural materials, composites offer a unique combination of properties of mechanical strength coupled with lightness in weight, resistance to corrosion, and both thermal and electrical insulation. The major disadvantages of known composite structures are their brittleness and high price. One of these structures currently in use in the aviation industry is Glare. The main application of Glare is this moment in the fuselage skin of the A380. Also, substitution of Glare-5 for the standard aluminium sheets is used in Boeing floors and it provides significant extension of the service life of the floors, reduce maintenance costs, reduce weight and provide protection against flame.

The NOVEL FIBRE METAL LAMINATES WITH HIGH IMPACT STRENGTH AND INTERNAL ENERGY DISSIPATION have significantly improved mechanical properties in comparison with all already developed fibre metal laminates structure (Glare, Arral): high impact strength, high energy-absorbing, elasticity under impact, low density, high tensile strength in all directions, high fatigue resistance, easy machining and fabrication, made from cost effective and standard materials (steel, aluminium, E-Glass fibre, Polyester Resin).

The elastic properties of continuous and unidirectional fibrous composites are highly anisotropic and depend of fibre orientation with respect to the applied stress. The axial tensile strength of a unidirectional lamina is typically controlled by the fibre ultimate strain. The transversal tensile strength of a unidirectional lamina is mainly controlled by the resin ultimate strain.

The strength of a fibre reinforced structure is up to 60 times greater in the longitudinal direction than in the perpendicular direction.

For achieving internal force-impact energy dissipation from transversal to longitudinal direction in the fibre reinforcements (Figure 1.), there are used unconventional materials in creation of Fibre Metal Laminates such as: Corrugated steel profile, Aluminum tube, Aluminum plate rigidised patterns and Aluminum ornamesh, that are serial, cost effective products of many manufacturers.

The achieved average mechanical properties of NOVEL FIBRE METAL LAMINATES WITH HIGH IMPACT STRENGTH AND INTERNAL ENERGY DISSIPATION structures are:

- Tensile Strength $\sigma > 1000$ MPa,
- Tensile Modulus $E = 32$ GPa,
- Density $\rho = 1300 - 2450$ kg / m^3.
- Peak Impact Force F = 184 kN (without penetration),
- Impact Energy Absorbed E = 3985 J (without penetration).

Significant and unique advantages of NOVEL FIBRE METAL LAMINATES WITH HIGH IMPACT STRENGTH AND INTERNAL ENERGY DISSIPATION structures to the Glare-5 (F = 10.3 kN, E = 150 J (with perforation) [*Polymer Composites, August 2000, Vol.21, No4.*]) are the level of impact resistance that is equal and even greater than that of Steel, and significant weight reduction (Glare density $\rho = 2160 - 2688$ kg/m^3). With superior weight to strength ratio, with only 5.75 kg/m^2 they can be used for any structural part.

Comparison of Specific Impact Energy absorbed between NOVEL FIBRE METAL LAMINATES WITH HIGH IMPACT STRENGTH AND INTERNAL ENERGY DISSIPATION panel thicknesses 3 mm and Steel Panel thicknesses 1.5 mm (500 x 500 mm) gives a ratio of 1510 J/kg : 1453 J/kg (peak Energy Absorbed 3985 J: 4272 J), with Deflection ratio of 41 mm: 69 mm.

More data are shown in Table 1.

Table 1. Comparison of some mechanical properties materials used in Automotive and Aviation Industry

Materials	Thickness [mm]	Specific Weight [kg/m^3]	Weight for 1mm Thickness [kg/m^2]	Weight per 1m^2 [kg/m^2]	Absorbed Impact Energy [J]	Specific Absorbed Impact Energy/Weight [J/kg]	Deformation [mm]	Peak Force [kN]	Tensile Strength [MPa]
Aluminium	1.5	2750	2.750	4.12	0	0	perforated	-	485
Steel	0.8	7850	7.280	6.40	0	0	perforated	-	655
Steel	1.5	7850	7.850	11.75	4272	1453	69	1.334	655
Honey.Comp.	4.3	1220	1.220	5.25	-	-	perforated	-	-
Glare-5	2.0	2590	2.590	5.18	150	-	perforated	10.3	-
JM 1	2.9	1972	1.660	5.72	3985	1510	41	184.3	>1000
JM 2	5.0	1860	1.860	9.30	3778	1108	13	153.9	>1000
JM 6	15.2	1404	1.400	21.35	3919	688	29	176.0	>1000
DYN 1	-	-	-	-	3727	-	perforated	91.7	-
DYN 5	-	-	-	-	4100	-	perforated	69.9	-

Legend:

- Data for Glare -5 used from "Application of Fibre-Metal Laminates", Polymer Composites, August 2000, [Absorbed Impact Energy (maximum) before perforation],.
- Data for DYN 1, and DYN 5 (Structures based on Kevlar reinforcements), form "Impact Testing in Formula One", A. N. Mellor, [Absorbed Impact Energy within displacement of 100 mm] Transport Research Laboratory, Crowthorne, Englasnd, ("ICRASH 2002" International Conference, February 2002, Melbourne,
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The fabrication process is based on the cost effective hand lay-up process where, with the use of some adhesives and curing under pressure at room temperature, use of expensive equipment and technologies such as autoclave or vacuum forming can be avoided (use of these technologies can only improve mechanical properties and abilities of NOVEL FIBRE METAL LAMINATES WITH HIGH IMPACT STRENGTH AND INTERNAL ENERGY DISSIPATION). They can be moulded or formed through other already known and used technologies in metal-plastic industry, with some minor adjustments, to form parts such as: basic car body, floor, roof, bonnet, wings in automotive industry or primary and secondary structures in aviation industry such as: the fuselage skin, leading edges of wings and tailplanes, floors, liners, foreplane, canard Wings, leading edge devices; fin fairings, wing skins and ribs, rudder, satellite structures,and flap skin material. Impact caused by birds and small debris from the landing strip would not cause any significant damage on the aircraft with use of NOVEL FIBRE METAL LAMINATES WITH HIGH IMPACT STRENGTH AND INTERNAL ENERGY DISSIPATION. The application of NOVEL FIBRE METAL LAMINATES WITH HIGH IMPACT STRENGTH AND INTERNAL ENERGY DISSIPATION can reduce the number of parts-positions in some sections because of their high and simple manufacturabilty.

The bonding capability of composites to materials like steel and aluminium means that product life can be extended by the use of corrosion resistant linings.

Use of NOVEL FIBRE METAL LAMINATES WITH HIGH IMPACT STRENGTH AND INTERNAL ENERGY DISSIPATION in Automotive, Aviation, Maritime, Space, Railway, Transportation and Building Industry can extensively substitute Steel and Aluminium, and other expensive sorts of materials such as: structures based on Aramid-Kevlar, Magnesium, Titan etc., because of significant advantages of NOVEL FIBRE METAL LAMINATES WITH HIGH IMPACT STRENGTH AND INTERNAL ENERGY DISSIPATION in area of mechanical properties, especially Impact and Fatigue Resistance, weight reduction, lower manufacturing cost, lower maintenance and repair costs. Various design-properties solutions, gives unlimited possibilities to create primary and secondary structures with highly controlled and predicted behaviour under loading.

That gives an opportunity to create structures with programmed and controlled behaviour of materials under different sorts of loading, especially under extreme (impact) loading that gives global opportunity to widespread application of high-tech materials in everyday products.

The claims defining the invention are as follows:

1. The NOVEL FIBRE METAL LAMINATES WITH HIGH IMPACT STRENGTH AND INTERNAL ENERGY DISSIPATION have significantly improved mechanical properties in comparison with all already developed fibre metal laminates structures.

2. The NOVEL FIBRE METAL LAMINATES WITH HIGH IMPACT STRENGTH AND INTERNAL ENERGY DISSIPATION has superior high impact strength, high energy-absorbing, elasticity under impact, low density, high tensile strength in all directions, high fatigue resistance, easy machining and fabrication, made from cost effective and standard materials.

3. Their impact energy absorption capacity are equal to these by the steel with up to 4 (four) times weight reduction for the same position.

4. Use of NOVEL FIBRE METAL LAMINATES WITH HIGH IMPACT STRENGTH AND INTERNAL ENERGY DISSIPATION in Automotive, Aviation, Maritime, Space, Railway, Transportation and Building Industry can extensively substitute Steel and Aluminium, and other expensive sorts of materials such as: structures based on Aramid-Kevlar, Magnesium, Titan, Glare, Arral, etc.

5. That gives an opportunity to create structures with programmed and controlled behaviour of materials under different sorts of loading, especially under extreme (impact) loading that gives global opportunity to widespread application of high-tech materials in everyday products.

AN APPLICANT

19. January, 2004.

Jasko Musaefendić

ABSTRACT

The NOVEL FIBRE METAL LAMINATES WITH HIGH IMPACT STRENGTH AND INTERNAL ENERGY DISSIPATION have significantly improved mechanical properties in comparison with all already developed fibre metal laminates structures. It has superior high impact strength, high energy-absorbing, elasticity under impact, low density, high tensile strength in all directions, high fatigue resistance, easy machining and fabrication, made from cost effective and standard materials. Their impact energy absorption capacity are equal to these by the steel with up to 4 (four) times weight reduction for the same position. Use of NOVEL FIBRE METAL LAMINATES WITH HIGH IMPACT STRENGTH AND INTERNAL ENERGY DISSIPATION in Automotive, Aviation, Maritime, Space, Railway, Transportation and Building Industry can extensively substitute Steel and Aluminium, and other expensive sorts of materials such as: structures based on Aramid-Kevlar, Magnesium, Titan, Glare, Arral, etc. That gives an opportunity to create structures with programmed and controlled behaviour of materials under different sorts of loading, especially under extreme (impact) loading that gives global opportunity to widespread application of high-tech materials in everyday products.

Figure 1. Force dissipation from transversal to longitudinal direction through internal layers of glass fibre reinforcements (basic principe).